Climate change impacts on upper ocean processes from atmospheric rivers using a high-resolution Earth System Model

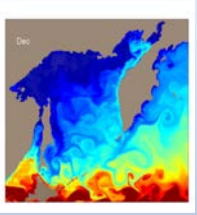
Christine A. Shields, Hui Li, Nan Rosenbloom, Sasha Glanville

National Center for Atmospheric Research

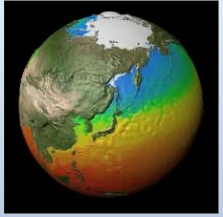
Image by NASA Earth Observatory - https://earthobservatory.nasa.gov

Climate Variability and Change Working Group Meeting, Feb 17th, 2022

Atmospheric Rivers: vehicles of moisture transport



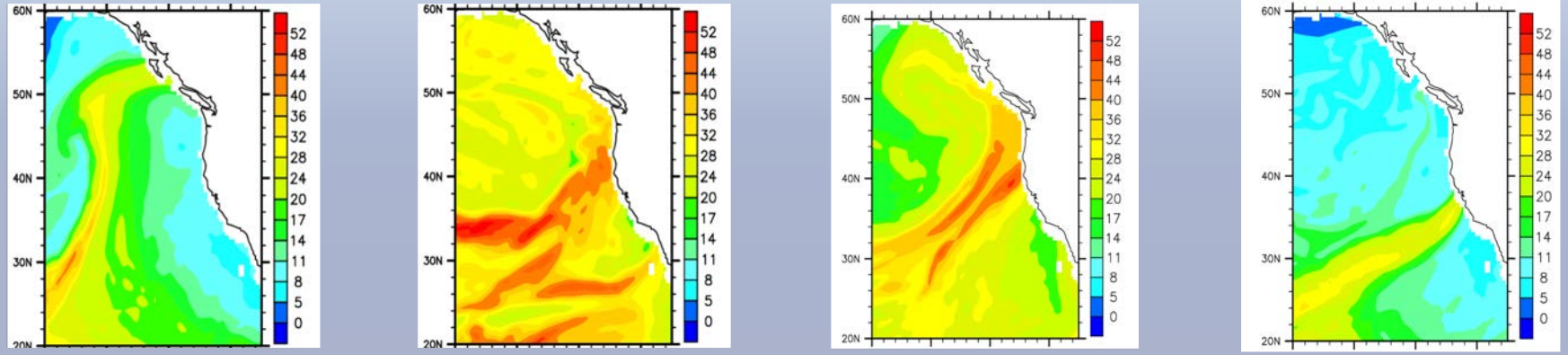
Eddy resolving CESM simulations



- CESM1.3 (“iHESP” version) ~0.25^{o} atmosphere/land and 0.1^{o} ocean/ice
- HighResMIP simulations protocol for control and transient
- Control 155 years
- Transient 1950 – 2050, using RCP8.5 forcing from 2006-2050
- Focusing on Eastern Pacific and landfalling ARs (Western North America)
- Use Shields and Kiehl ARDT, designed for high resolution climate data. Relative time-independent method (spatial not temporal anomalies), designed to detect strongest ARs, restrictive compared to ARTMIP ARDTs.

Identifying ARs in gridded or model data

Integrated Water Vapor kg/m^2



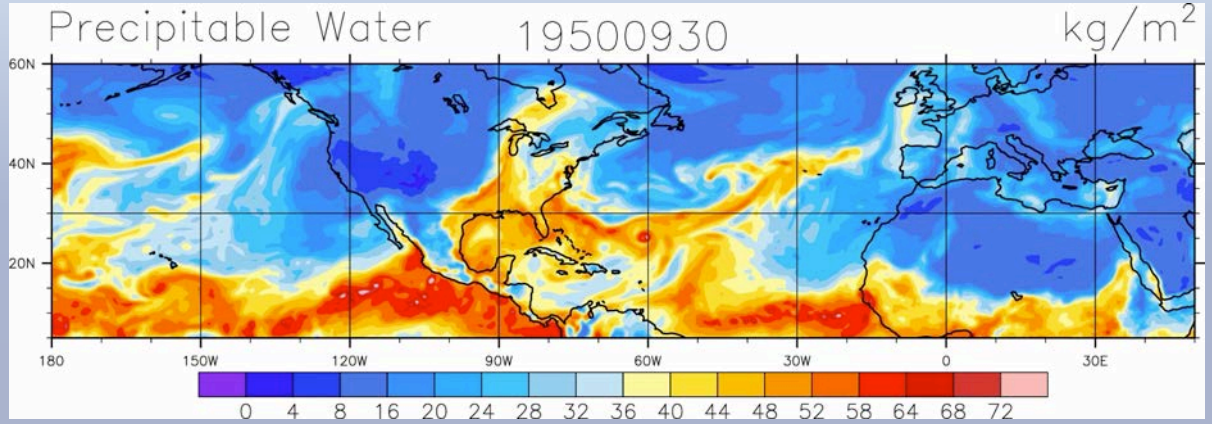
Shields/Kiehl ARDT: Different flavors of strong ARs relative to their environment (not temporal climatology)

$$|Q_{threshold}| >= |Q_{mean}| + Q_{coef}(|Q_{max} - Q_{mean}|)$$

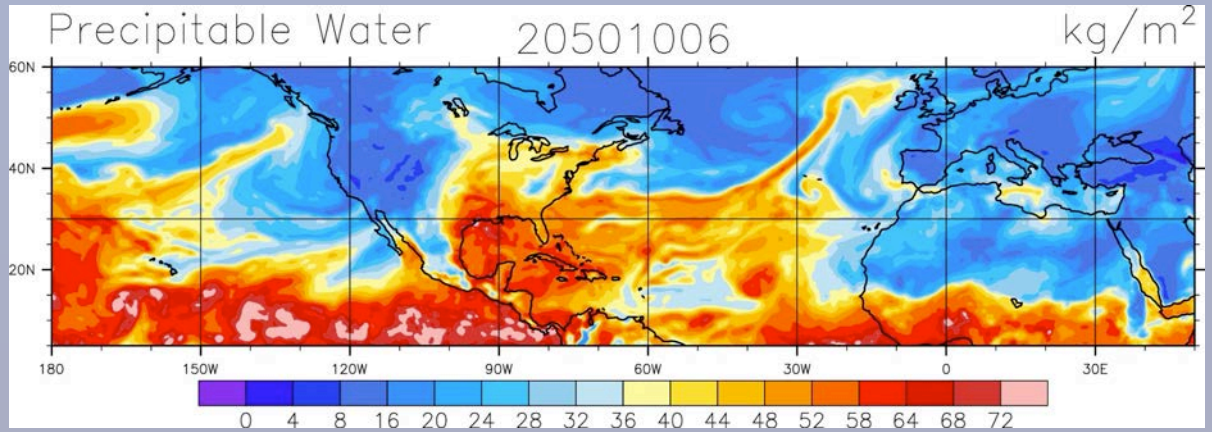
Q = Moisture variable, i.e. IWV

Mean = zonal mean, Max = zonal maximum, coef = 0.3 (Zhu and Newell, 1998)

Movies of ARs with high resolution (0.25_.01)



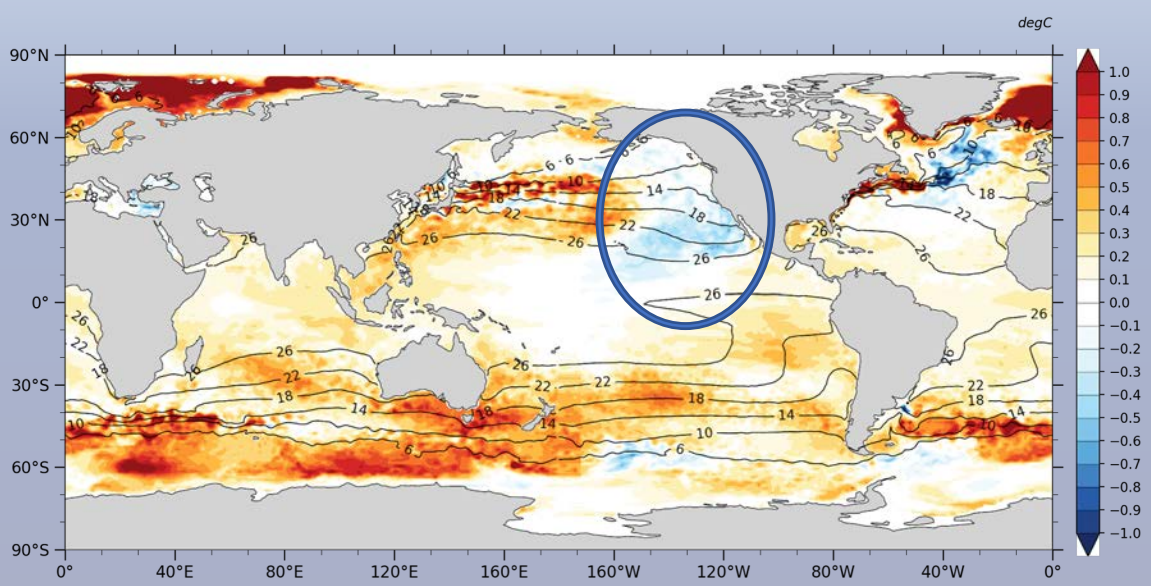
1950 Oct through Dec

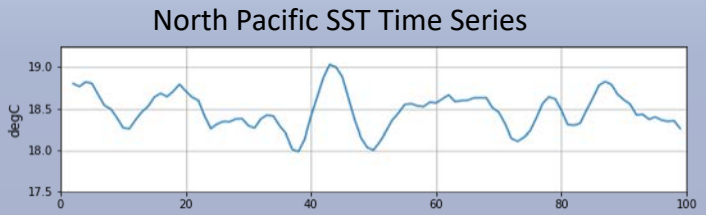


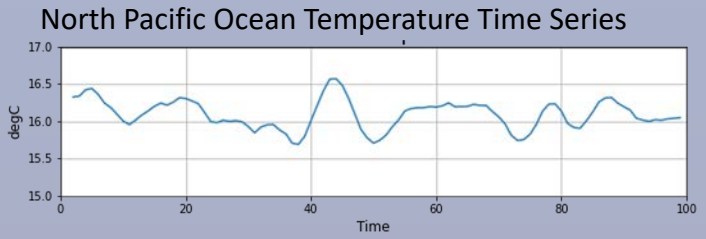
2050 Oct through Dec

Does the drift in the HighResMIP simulations impact AR statistics?

SST





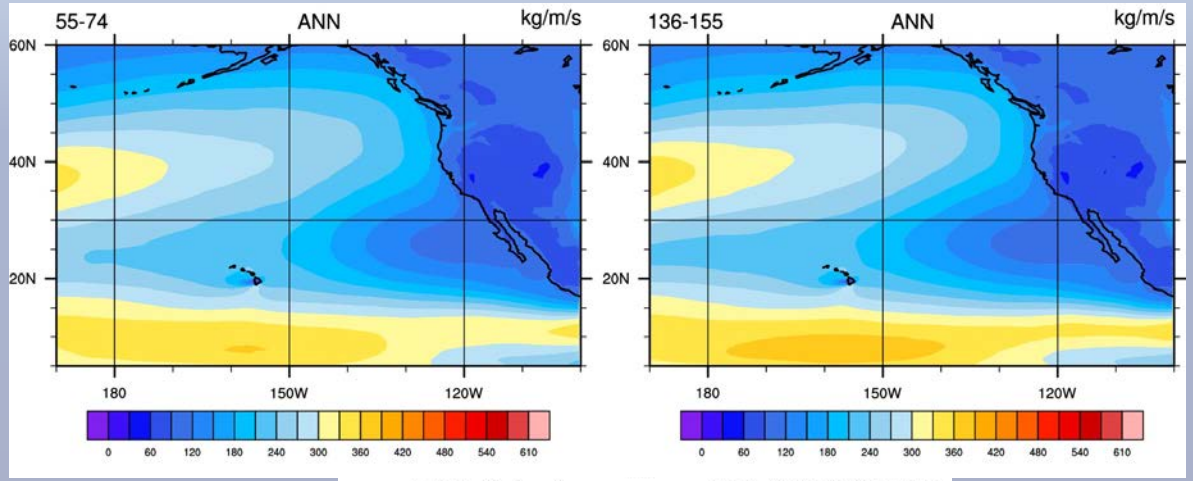


- End control – Begin control (20 yr means)
- 155 years in control

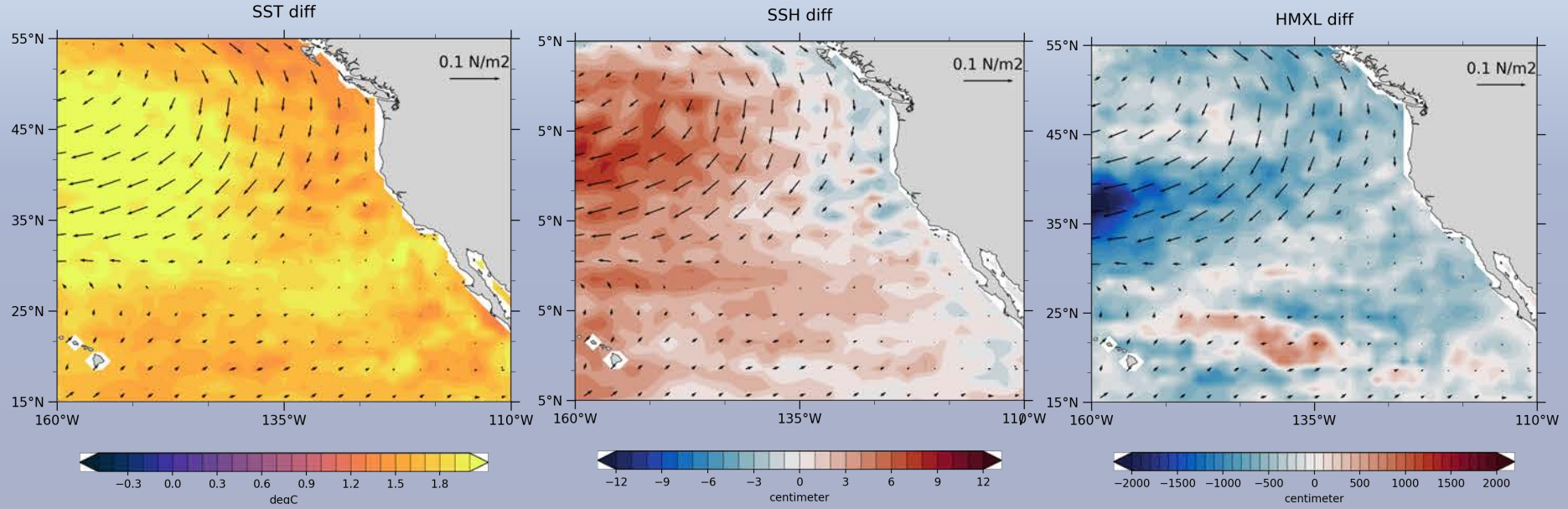
Does the drift in the HighResMIP simulations impact AR statistics?

IVT **Integrated Water Vapor Transport**

- ARDT is time-independent and relative methodology and is NOT dependent on temporal climatology.
- Slight increase in IVT magnitude does not significantly impact detection due to threshold dependance on spatial anomaly.
- Increase is in local maxima intensity, not in jet position.



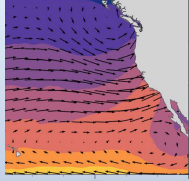
Cold Season Climatology: 2031-2050 minus 1950-1969

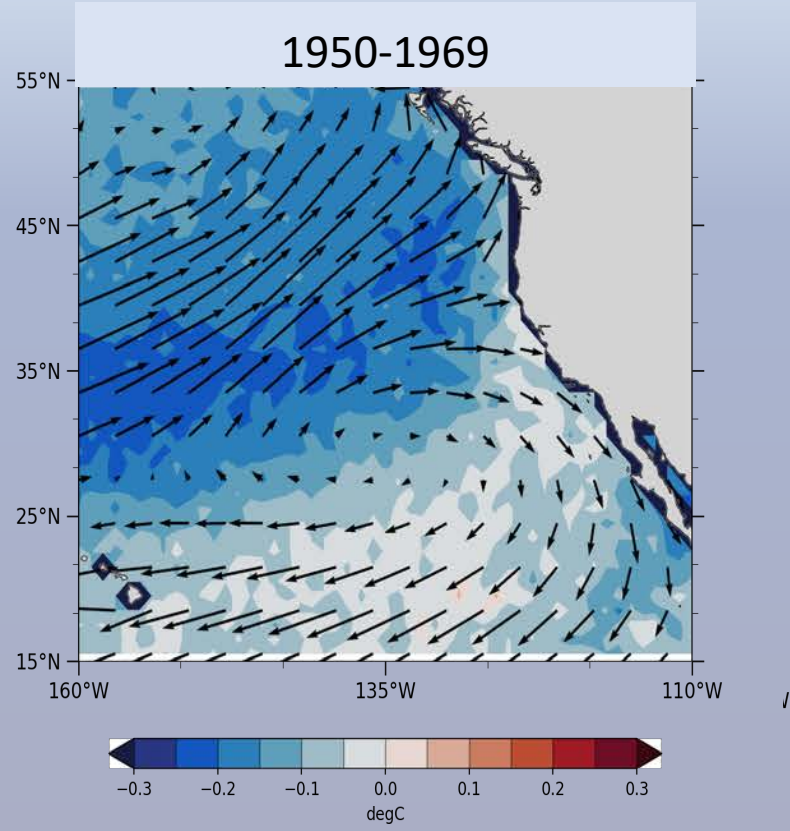


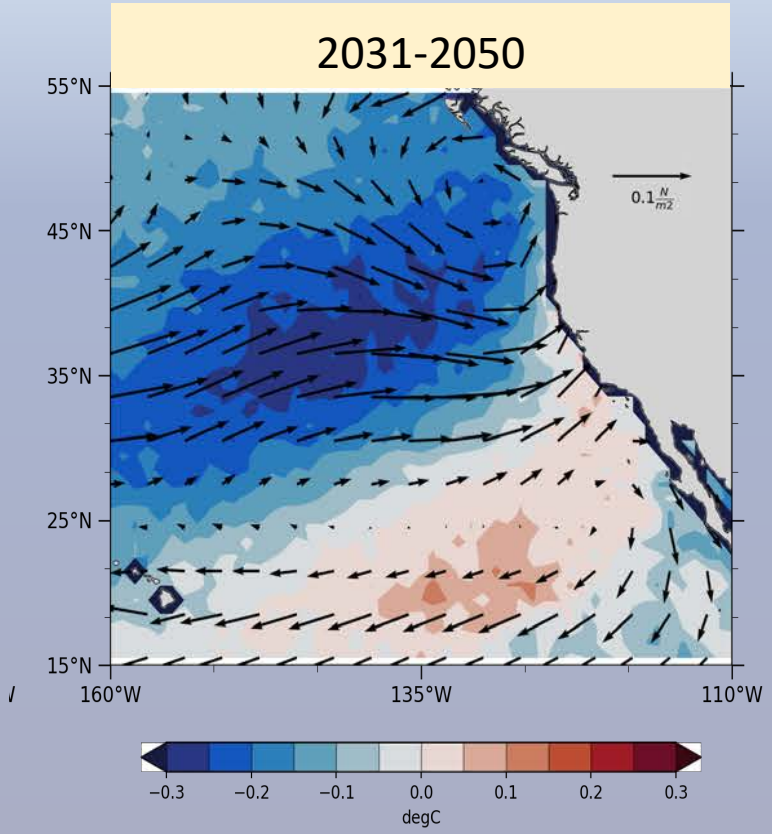
- Warmer SST
- Increased SSH increased except near land
- Shallower mixed layer depth
- Vector arrow are wind stress (Nm^{-2})

SST

AR Composites Southern California





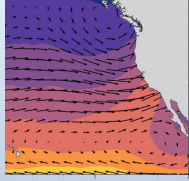


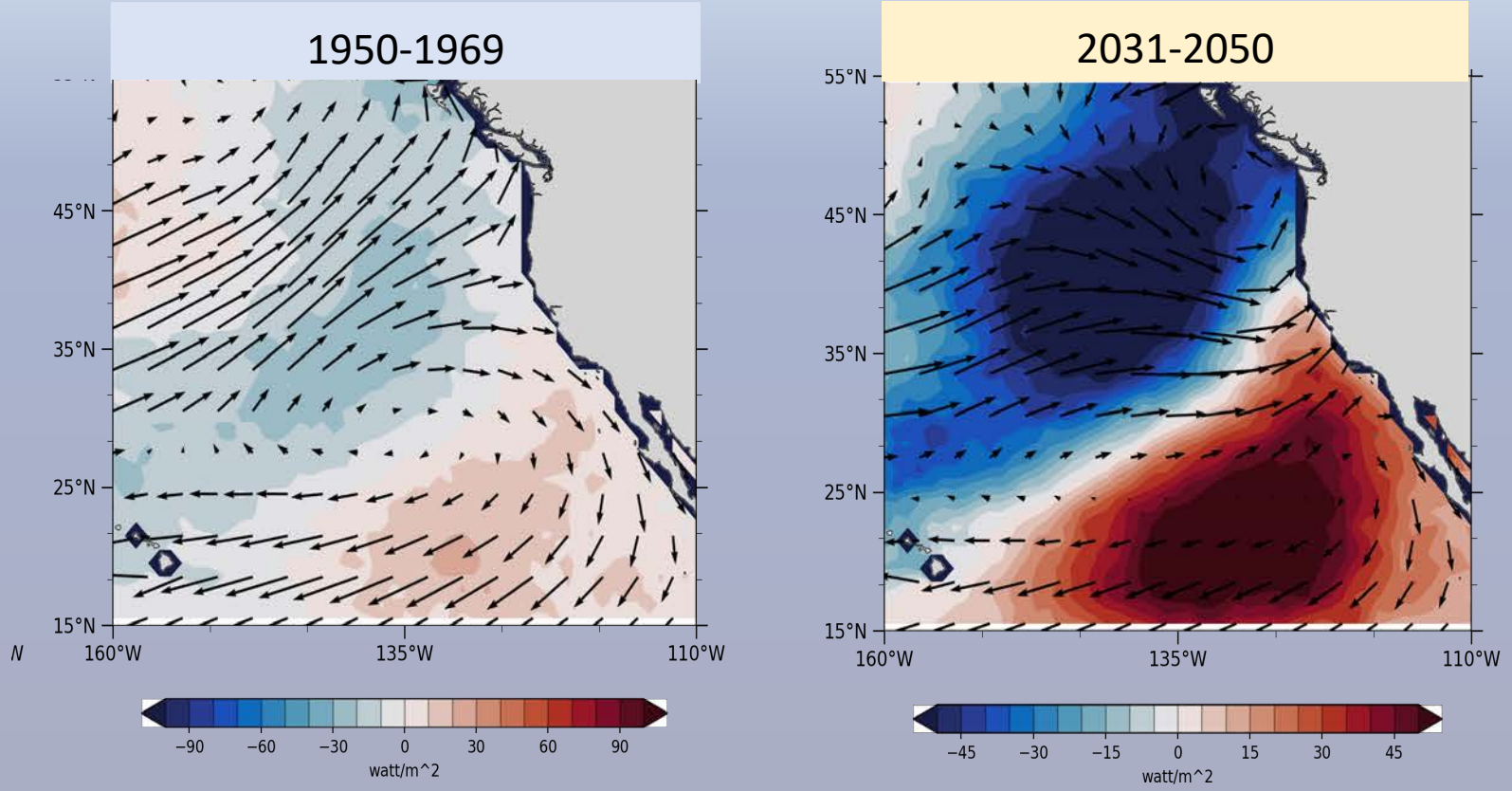
Colors = Anomalies from Climatology

Vectors = Composite AR wind stress (Nm^{-2})

Sfc Heat Flux

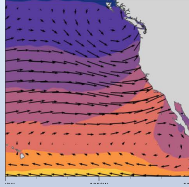
AR Composites Southern California

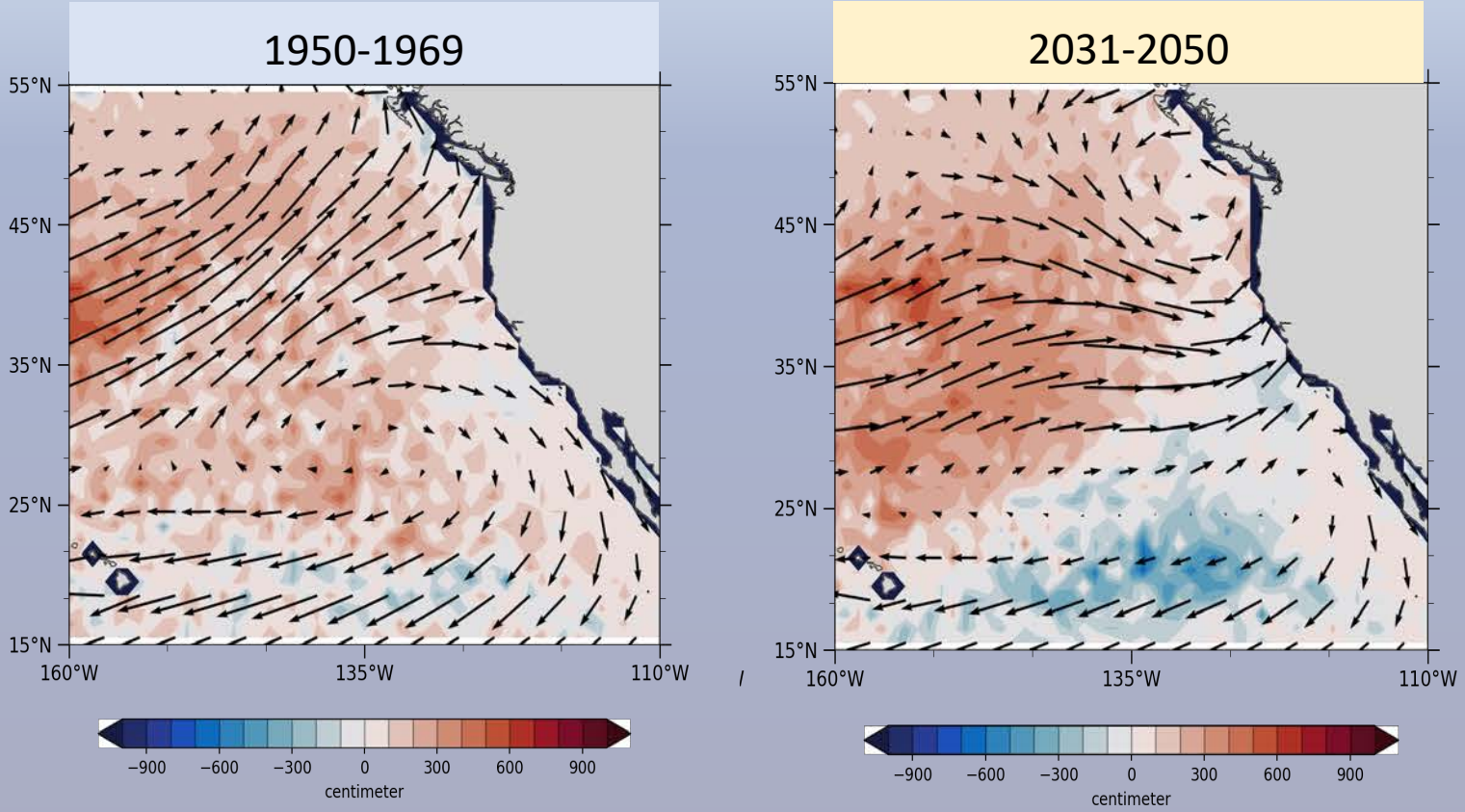




Mixed Layer Depth

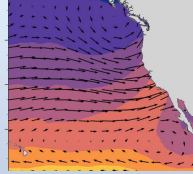
AR Composites Southern California

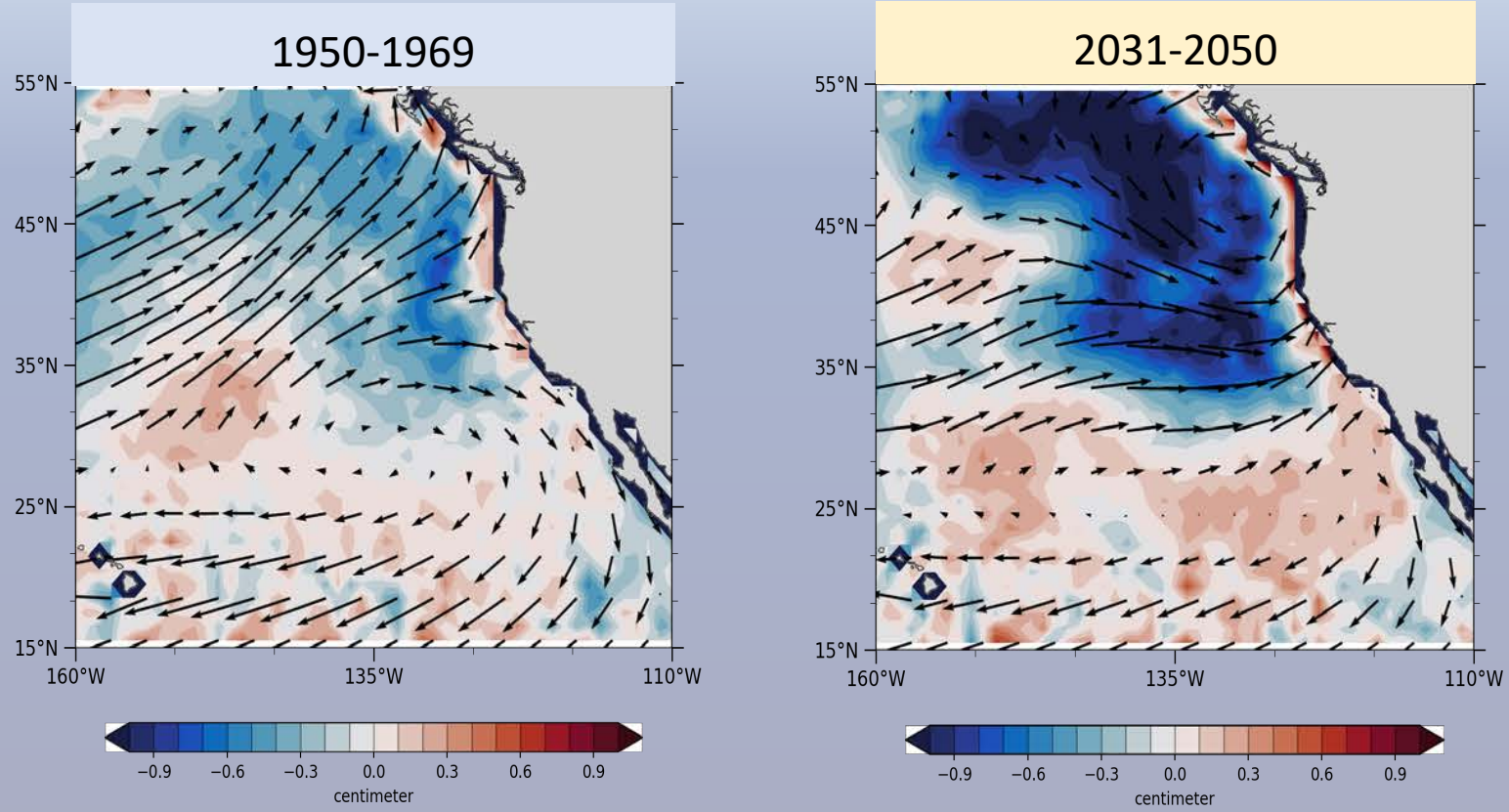




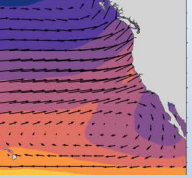
AR Composites Southern California

Sea Surface Height



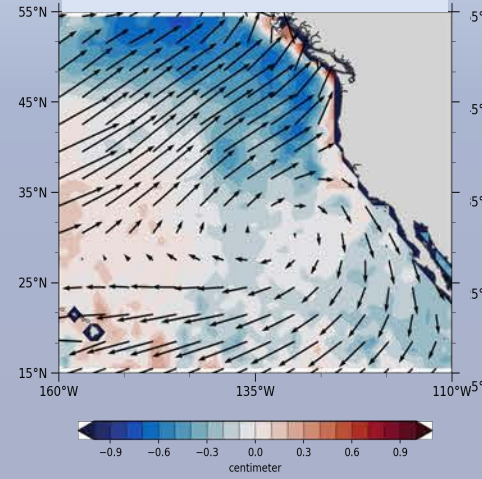


More Sea Surface Height…

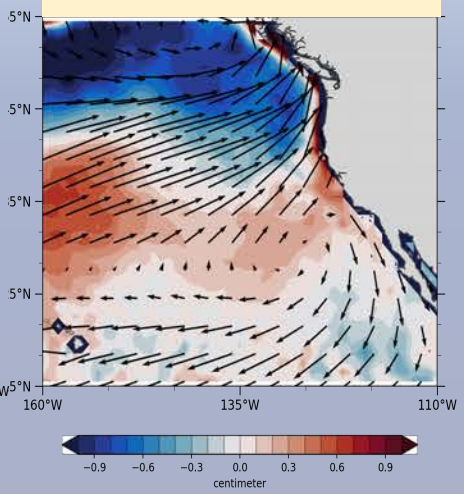


CA

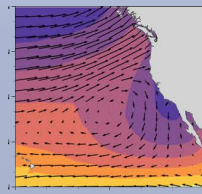
1950-1969



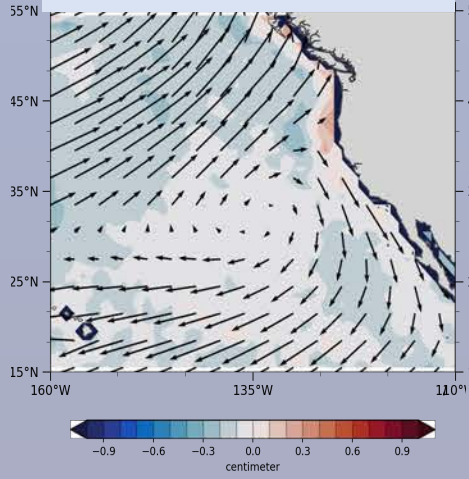
2031-2050



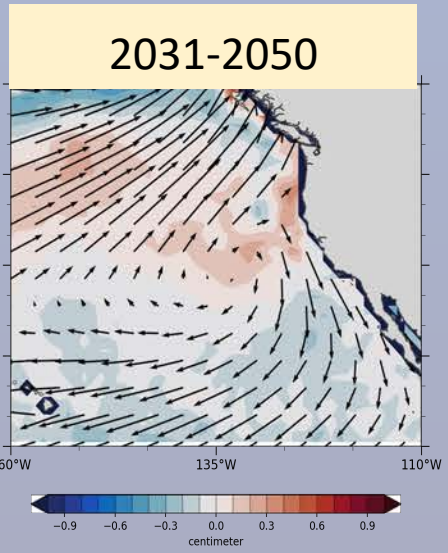
PNW



1950-1969

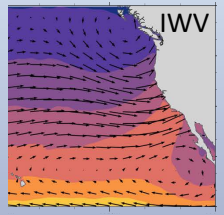


2031-2050

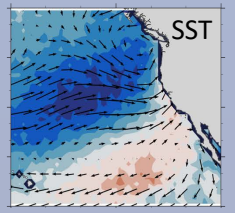


Key Points and Next Steps

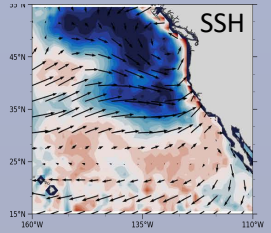
- Feedbacks between ARs and the upper ocean are detected in high resolution atmosphere and ocean model for Pineapple Express ARs in the North Pacific.



- Decrease in SSTs, surface heat flux, and increase in mixed layer depth are found in waters behind the ARs. Under climate change this relationship strengthens, but for Southern CA ARs, warmer and shallower water is found ahead of the AR.



- Sea surface height responds to AR wind flow by pushing water towards the coast. Under climate change, this relationship is strengthened for California, but SSH response for PNW is less clear.



- Repeat analysis with additional historical and RCP8.5 simulations based on equilibrated control, expand AR region and flavors.